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A STUDY OF NITRIFICATION IN PHILIPPINE SOILS

By Elias H. Pañganiban

Thesis presented for graduation from the College of Agriculture No. 32

Historical Introduction.

The fertility of a soil has been defined as its crop producing power or the productiveness under given conditions; and it is now believed that the productiveness or crop producing power of any soil depends upon three main factors, namely: its chemical, physical, and bacteriological characteristics.

The chemical and the physical characters of the soil, when determined by the methods which are at present known, alone will not fully ascertain the soil's value and fertility. The insoluble, unavailable plant food must first be transformed into readily available nourishment for plants, and this transformation is largely due to the soil bacteria.

Liebig and other early agricultural chemists considered ammonia (NH_3) to be the most useful form of nitrogen for plants, but experimental evidence demonstrated that fertilization of the soil with nitrates gave decidedly good results, and about 1861, work was published that explained the very rapid nitrification of ammonium salts going on in the soil as due to the bacterial action. It was also demonstrated that the nitrates formed are the best source of nitrogen for most plants, so that the practical importance of the process of nitrification was established.

The advantages of nitrate fertilizers as compared with ammonium salts, are as follows:

First: Ammonium salts must undergo the nitrification process, namely, must be transformed into nitrates before they can be readily used as food for most plants.

Second: Ammonium salts, if applied on soil that is poor in limestone, tend to make the soil acid and only plants that are able to withstand high soil acidity will grow well with such treatment.

Third: In soils that are rich in limestone the nitrogen of the ammonium salts tends to be lost as gaseous ammonia, and there is danger at the same time of injuring plants because of the corrosive action of ammonium carbonate or the ammonia that may result through its decomposition.

On the other hand, ammonium salts or organic nitrogen fertilizers are less readily leached from the soils than nitrates; for this reason, the ideal method of applying nitrogen as a fertilizer would be to employ ammonium salts or organic nitrogen, trusting to the process of nitrification brought about through the action of bacteria to transform the nitrogen of these materials into the more readily assimilable nitrate-nitrogen.

Many experiments have been undertaken to determine the rate at which nitrification takes place in soils, but almost every such test has been made in the temperate zone,

and no such study has ever been published for Philippine soils; for this reason, the experiments about to be described were undertaken. In order that the methods employed may be the more readily understood, and in order that the results may be compared with those gotten elsewhere, the experimental part of this paper is preceded by a discussion in which the most important literature of the subject has been reviewed.

Discussion of the Nitrification Process.

Originally it was supposed that the formation of nitrate-nitrogen in the soil was due to the organic catalytic agents of the soil, but latter it was shown to be due to microorganisms(1). Some of these microorganisms oxidize ammonia to nitrous acid and others begin with nitrous acid and carry the oxidation to nitric acid or nitrates(2, 3). These two nitrifying bacteria are classified as nitrite- and nitrate-formers, known respectively as Nitrosomonas and Nitromonas. (4, 5, 6) But apart from these bacteria there is an organism that can oxidize ammonia directly to nitrate called B. nitrator.(7) However the exact process by which ammonia is oxidized to nitrites and nitrites in turn to nitrates is still unknown, though it is supposed that this action takes place at the same time that carbon dioxide (CO_2) is assimilated by the bacteria from the atmosphere and that the two processes are connected in some way.

Very rich application of stable manure, green manure, calcium cynamid, etc., may at times hinder nitrification or even bring about denitrification with the loss of nitrogen, but it is believed that this seldom happens under practical field conditions.

In nature the two processes of nitrite- and of nitrate-formations run concurrently; but in artificial cultures the latter process may be repressed by the addition of free ammonia or ammonium carbonate, or by the addition to the culture of rather considérable quantities of sodium carbonate or basic magnesium carbonate. Chalk does not appear to be able to check the second stage of nitrification in the presence of ammonium salts(1).

Nitrification takes place readily in solution if ammonium salts be added in very small amounts, at widely separated intervals of time, in order that the nitrifying organisms may have time for a vigorous development.(2, 3, 4) In solutions, nitrification may be quite as great as in soils, providing that the height of the liquid is sufficiently small; and it has been found that the rate of nitrification is nearly proportional to the surface in contact with the atmosphere when the same volume of liquid is exposed in layers of different depth.(5, 6)

The rate of nitrification is influenced especially by aeration, moisture, temperature, time of the year, and kind of soil. It has been frequently noticed that sandy soil, in case it is so porous as to have but little moisture-holding capacity, permits nitrification to take place more rapidly than does clay soil, and that the addition of sand to soil that is rich in nitrogen will increase the rate of nitrification(7). Ammonium carbonate has been found to be more quickly nitrified than ammonium sulphate and ammonium phosphate, while free ammonia does not appear to be oxidized at all and may even check nitrification. The ammonium salts of the organic acids are readily nitrified(8).

Moisture appears to be of greater influence than aeration, for the nitrifying bacteria have been found at a great depth and are able to live and bring about nitrification in an atmosphere containing but 6% of oxygen (9). Nitrification was found to be very

(1) Schlosing et Muntz, Compt rend. (Paris), 84, (1877) 301-303; *85*, (1877) 1019-1020.

This and following references to periodicals are taken from Lohnis, "Handbuch der Landwirtschaftlichen Bakterlodgie", Berlin: Gob. Borntraeger, (1910).

(2) Schonbein (Verh. d. naturf. Gesellsch. in Basel *3* (1861) 216 ff.)

(3) Al. Muller (Landw. Vers.-Stat., *27*, (1882) 338.)

(4) P. and G. Frankland, Philos. Transact. Roy. Soc, London, B, *181*, (1890) 107-128.

(5) Warington, Journ. Chemic, Soc., *59*, (1891) 484-529.

(6) Winogradsky, Ann. de l'Inst. Pasteur, *5*, (1891) 577-616.

(7) C. E. Marshall, "Microbiology", 259.

(1) Warington, Journ. Chemic Soc., *59*, (1891) 484-529; Hj. Jensen, Tidskr. f. Landbrugets Planteal, *5*, (1899,) 173; Migula, Zentralbl. f. Bakt., II Abt., *6*, (1900,) 370; Remy, Ibid. *8*, (1902,) 701; P. Ehrenberg, Landw. Jahrb.. *33*, (1904) 46; Lipman and Brown, Ibid. (1908,) 117 ff.:

(2) Boullanger et Massol, Ann. de l'Inst. Pasteur, *18*. (1904) 189 ff.

(3) Burri und Stutzer, Zentralbl. f. Bakt , II. Abt., *2* . (1896) 114, 204.

(4) Demoussy, Compt. rend. (Paris), *128*, (1899,) 566-569, Ann. agron., *25*, (1899,) 97 (ref. Zentralbl. f. Agric Chemie, *28*, (1899,) 783).

(5) Schlosing and Muntz, 1. c. (1879), 1074-1077.

(6) Lohnis, Mitt. landw. Inst. Leipzig, *7*, (1905,) 89.

(7) Dehérain, Ann. agron., *13*, (1887,) 241 (ref. Zentralbl. f. Agric. Chemie, *16*, (1887,) 728.)

(8) Schultz—Schultzenstein, Mitt. a. d. Prüfungsanstalt f. Wasserversorgung and Abwasserbeseitigung Berlin, 2, (1903,) 17.

(9) Schlosing, Compt. rend (Paris), 77, (1873.) 720.

slight when the soil contained 5% moisture; with 10% moisture it was plainly noticeable, while with 15—20% it reached its maximum and with higher percentages fell off again(1.) Nevertheless this optimum percentage of moisture would naturally depend on the water capacity of the soil; and in the writer's experiments, to be given later, as much as 40% moisture seemed to be necessary to bring about the most rapid nitrification.

By using in every case 100 grams of mixed sand and clay, 100 milligrams ammonium sulphate, 1 gram of chalk, and 9.5 grams of water, the nitrification in 2 weeks varied from 2.2 milligrams in the case of material that was 70% sand and 30% clay to 80 milligrams in the case of material that was 80% sand and 20% clay, while with increasing weight of sand the nitrate formed decreased again to 51 milligrams. These differences are supposed to be due mainly to the different water capacity of the mixtures, since in each case 9.5 grams of water were used. (2)

It has been found that the nitrifying bacteria show very little resistance to drying. The nitrite bacteria in the zooglea form will stand 24 hours drying in the air while those in the monad form are killed by this treatment.

At 5° C. nitrification is very slow, at 12° C. it is plainly noticeable and reaches its optimum at 35-37° C, which is about the soil temperature for tropical countries at a slight depth below the surface. A temperature of about 30° C., according to Warington, gives relatively much nitrite(3).

Experimental Part.

Soils used:

1. Soil A.—From a field of yautia, northeast of the main building of the College of Agriculture, and about 72 meters from its nearest corner. This has been in cultivation since 1912 with corn, beans, corn and yautia in succession.

2. Soil B.—From a field of corn, north of the laboratory building of Physics and Botany, and about 80 meters from its nearest corner. This also has been in cultivation since 1912 but with corn, beans, and corn in succession.

3. Soil C.—From banana plantation, 15 meters east of the silk house. Before September, 1912, that is, before it became a banana plantation, it was under cultivation with guinea grass.

4. Soil D.—From the nursery, directly south of the concrete stable and about 50 meters from its nearest corner. It has now been in cultivation for four or five years with different horticultural and agricultural plants.

5. Soil E.—From the corn field southeast of the concrete stable, on the opposite side of the Molawin River, at a distance of about 250 meters from the stable. It has now been in cultivation for a year with corn. Before this it had been uncultivated for an unknown length of time.

6. Soil F.—From a garden on the hill 50 meters south of concrete monument No. 7, "Map of the New Farm". It has been cultivated about one and a half years to corn, sweet potatoes and cowpeas; formerly it was a cogon area.

Sources of Nitrogen:

1. Ammonium sulphate fertilizer containing 20% of nitrogen.

2. Dried blood fertilizer containing 8.17% of nitrogen.

Sampling:

The soil samples were taken from the fields to a depth of six inches by means of a trowel sterilized in a flame. The samples were mixed in the laboratory on an oil cloth which had been sterilized with formalin. They were dried in the air for two or more days, depending upon their moisture content, then gently ground in a mortar and passed through a sterile sieve. The sifted soils were thoroughly mixed after which operation they were ready for the experiments.

In the first set of experiments, the samples from fields A, B, C, D, were taken November 24, 1914; from field E, November 30, 1914; from field F, December 5, 1914. The writer believed that the different dates of collecting the samples from the fields will not affect the rate of nitrification of the soil, because before the test was run, the soils were all air-dried, a treatment which would tend to equalize such factors as the moisture content, temperature, etc., that might otherwise influence nitrification.

Methods.

In undertaking the experiments, the writer

(1) F. Lohnis, "Handbuch der Landw. Backteriologie", p. 616.

(2) Schlosing fils, Compt. rend. (Paris), *125*, (1897,) 826; Lipman and Brown, Ann. New Jersey Agric. Exp. Stat., *29*, (1908,) 177-122.

(3) Warington, Jour. Chemic. Soc., *59*, (1891,) 484.

followed with some slight modifications Lipman's directions (1) for the study of nitrification, This is the "beaker" method, which is so far the best method known. The beakers, with the Petri dish covers, were sterilized in an autoclave till the manometer registered 2 atmospheres pressure. After cooling, the air-dried, sifted soils were placed in the beakers in 100 gram portions. Having done this, the proper amount of materials—100 milligrams of ammonium sulphate, and 200 milligrams of dried blood-were added and stirred in thoroughly with a sterile spatula. Inocultation was accomplished by the addition of 10 cubic centimeters of an infusion prepared from fresh samples of the soils, this amount being equivalent to 5.0 gms. of soil. The moisture was determined by drying a very small portion of air-dried soil in an oven at 100°C to constant weight. The loss in weight gives the moisture content and knowing this, it was easy to calculate the amount of water needed to bring the moisture in the 100 gram samples up to 22%, the desired value. The beakers were covered with Petri dish covers and incubated for 4 weeks, the moisture condition being maintained at to the percentage given above by addition of water loss by evaporation every 10 days. At the end of the incubation period, 2 grams of calcium hydroxide were added to each sample, (to precipitate clay) and the samples then leached to give 500 cubic centimeters of filtrate. The nitrate-nitrogen in each sample was determined in aliquot portions by the phenolsulphonic acid (colorimetric) method, as given below.

Ten cubic centimeters were evaporated in a small porcelain evaporating dish on the water bath, one cubic centimeter of phenolsulphonic acid added and quickly and thoroughly incorporated with the residue by aid of a glass rod. After allowing the phenolsulphonic acid to react with the nitrates for 15 minutes ten cubic centimeters of distilled water were added and the mixture well stirred with a glass rod. Ten cubic centimeters of ammonium hydroxide were added to render the liquid alkaline, and then the mixture transfered to Nessler's tubes and diluted to the 100 c. c. mark with distilled water. If the nitrates were present there would be formed a yellow color which were compared with permanent standards made for the purpose, by putting the following quantities of the standard solution into 100 cubic centimeters Nessler's tubes, adding 5 cubic centimeters of strong ammonium hydroxide to each tube, namely, 5 c.c., 10 c.c., 15 c.c., and 20 c.c., and making up to the 100 c.c. mark with distilled water. The comparison with the standards was made by looking down vertically through the tubes at a white surface in front of a window. From the relative volumes contained in the comparison tubes, the amount of nitrates present in the solution was calculated.

The experiments were run in duplicate and the conclusions are based on the average of the results.

Results.

The quantitative determinations in the first set of experiments, after the soils had been incubated for four weeks beginning December 3, 1914 at room temperature (24-30° C.), gave the results found in the following tables:

TABLE I. SOIL A.

Sources of Nitrogen.	Nitrate nitrogen. mg.	Aver. of nitrate nitrogen. mg.	Increase over untreated portion mg.	Percent nitrified.
Nothing	1.66	1.62		
Nothing	1.58			
100 mg. $(NH_4)_2SO_4$	6.66	6.77	5.15	25.75
100 mg. $(NH_4)_2SO_4$	6.89			
200 mg. Dried blood	5.55	5.55	3.93	24.05
200 mg. Dried blood	5.55			

TABLE II. SOIL B.

Sources of Nitrogen.	Nitrate nitrogen. mg.	Aver. of nitrate nitrogen. mg.	Increase over untreated portion. mg.	Percent nitrified.
Nothing	2.50	2.56		
Nothing	2.62			
100 mg. $(NH_4)_2SO_4$	9.09	8.90	6 34	31.70
100 mg. $(NH_4)_2SO_4$	8.72			
200 mg. Dried blood	6.89	6.89	4.33	26.49
200 mg. Dried blood	6.89			

(1) Lipman Manual of Agricultural Bacteriology" Exercise 20.

TABLE III. SOIL C.

Sources of Nitrogen.	Nitrate nitrogen. mg.	Aver. of nitrate nitrogen. mg.	Increase over untreated portion. mg.	Percent nitrified.
Nothing	1.72	1.69		
Nothing	1.66			
100 mg. $(NH_4)_2SO_4$	6.89	7.01	5.32	26.60
100 mg. $(NH_4)_2SO_4$	7.14			
200 mg. Dried blood	5.68	5.78	4.09	25.03
200 mg. Dried blood	5.88			

TABLE IV. SOIL D.

Sources of Nitrogen.	Nitrate nitrogen. mg.	Aver. of nitrate nitrogen. mg.	Increase over untreated portion. mg.	Percent nitrified
Nothing	2.63	2.59		
Nothing	2.56			
100 mg. $(NH_4)_2SO_4$	10.52	10.81	8.22	41.10
100 mg. $(NH_4)_2SO_4$	11.11			
200 mg. Dried blood	7.14	7.10	4.51	27.60
200 mg. Dried blood	7.06			

TABLE V. SOIL E.

Sources of Nitrogen.	Nitrate nitrogen. mg.	Aver. of nitrate nitrogen. mg.	Increase over untreated portion. mg.	Percent nitrified.
Nothing	3.56	3.53		
Nothing	3.51			
100 mg. $(NH_4)_2SO_4$	13.76	13.94	10.41	52.05
100 mg. $(NH_4)_2SO_4$	14.12			
200 mg. Dried blood	8.14	8.27	4 74	29.01
200 mg. Dried blood	8.41			

ATBLE VI. SOIL F.

Sources of Nitrogen.	Nitrate nitrogen. mg.	ver. of nitrate nitrogen. mg.	Increase over untreated portion. mg.	Percent nitrified.
Nothing	4.54	4.44		
Nothing	4.35			
100 mg. $(NH_4)_2SO_4$	16-66	17.42	12.98	64.90
100 mg. $(NH_4)_2SO_4$	18.18			
200 mg. Dried blood	10.00	10.26	5.82	35.62
200 mg. Dried blood	10 53			

From consideration of the results given in the six tables above, several facts might be deduced. The soils which were taken for the nitritification experiments, though chemically much the same, were decidedly different in nitrifying power. The different soils used are all at present under cultivation with different crops, but the time at which they were brought into cultivation was not the same. Now, since the nitrifying power of the soil is due to the action of bacterial flora of the soil, and since the bacterial content of the soil is influenced by many factors (1) such as the crop present on the soil, the rotation of the crop, the treatment of the soil, the soil humidity, the disposal of the crop, etc., the rate of nitrification observed in the soils tested must then be expected to differ, altho the experiments cited above do not in fact show large variations in the nitrifying power of the soils studied.

The soil used in Table I (Soil A) is in rotation with, since it was first cultivated and at present it is planted with yautia, while Soil C of Table III has been in continued cultivation with bananas since September 1912. P. E. Brown (21) in his studies on the effect of different crops on the numbers and activities of certain kinds of bacteria, gave as his conclusion that continuous cropping either to corn or to clover exhausts the soil both chemically and bacteriologically. In our own work, the field under continued cultivation with guinea grass followed by bananas gave a slow rate of nitrification as is shown in Table III. But Soil A (Table I) is in rotation and also gave a low nitrification power, occurrence perhaps accounted for by the fact that it is a rather shallow soil and has grown corps continuously for three years.

Table V and Table VI show that the soils E and F have a greater nitrifying power than the rest. This fact seems to indicate that soils but recently brought under cultivation have a higher rate of nitrification than similar soils that have grown many crops.

Turning now to the results of ammonium sulphate and dried blood as a source of nitrogen for the nitrifying bacteria, it is evident from the data given above that in all cases the nitrification with ammonium sulphate is greater than with dried blood; the reasons being, first, that the 100 milligrams of ammonium sulphate contain a

(1) P. E. Brown, "Bacteriological Studies of Fields Soils. (Bul. Agr. Expt. State Iowa State Col. of Agric. and the Mechanic Arts). II. 6. (1912) 226.

greater amount of total elementary nitrogen (20 mg.) than the 200 milligrams of dried blood (16.38 mg.); and second, that the ammonium sulphate is soluble and therefor more susceptible to nitrification than the dried blood. These two facts are confirmed by the amounts of nitrogen converted as given in the above tables, showing that in most cases, with dried blood as a source of nitrogen the resulting percentages are lower than with ammonium sulphate.

A second set of experiments was undertaken in order to confirm the previous work and ascertain what effect calcium carbonate added to local soils has on nitrification. The soil samples used, A to E inclusive, were taken from the fields January 26, 1915; soil F, January 27, 1915. No ammonium sulphate was used, 200 milligrams of dried blood and 1 gram of calcium carbonate being substituted thus showing the effect of this substance on the nitrification of dried blood. After incubation for four weeks beginning January 28, 1915 at room temperature (24-30° C.), a quantitative determination of nitrate-nitrogen was made by the method previously described. The results are given in the following tables:

TABLE VII. SOIL A.

Sources of Nitrogen.	*Nitrate nitrogen.* mg.	*Aver. of nitrate nitrogen.* mg.	*Increase over untreated portion.* mg	*Percent nitrified.*
Nothing	2.13	2.15		
Nothing	2.18			
200 mg. D. B. + 1 gm. $CaCO_3$	9.09	9.67	7.52	46.02
200 mg. D. B. + 1 gm. $CaCO_3$	10.26			
200 mg. D. B.	6.89	6.94	4.79	29.31
200 mg. D. B.	7.00			

TABLE VIII. SOIL. B.

Sources of Nitrogen.	*Nitrate nitrogen.* mg.	*Aver. of nitrate nitrogen.* mg.	*Increase over untreated portion.* mg.	*Percent nitrified.*
Nothing.	3.13	3.05		
Nothing.	2.97			
200 mg. D. B. + 1 gm. $CaCO_3$	12.23	12.34	9.29	56.85
200 mg. D. B. + 1 gm. $CaCO_3$	12.45			
200 mg. D. B.	8.56	8.59	5.54	33.99
200 mg. D. B.	8.62			

TABLE IX. SOIL C.

Sources of Nitrogen.	*Nitrate nitrogen.* mg.	*Aver. of nitrate nitrogen.* mg.	*Increase over untreated portion.* mg.	*Percent nitrified.*
Nothing	2.52	2.59		
Nothing	2.66			
200 mg. D. B. + 1 gm. $CaCO_3$	11.07	10.61	8.02	49.09
200 mg. D. B. + 1 gm. $CaCO_3$	10.15			
200 mg. D. B.	7.84	7.84	5.75	32.14
200 mg. D. B.				

TABLE X. SOIL D.

Sources of Nitrogen.	Nitrate nitrogen. mg.	Aver. of nitrate nitrogen. mg.	Increase over untreated portion. mg.	Percent nitrified.
Nothing	3.23	3.28		
Nothing	3.33			
200 mg. D. B. + 1 gm. $CaCO_3$	13.66	13.69	10.41	63.72
200 mg. D. B. + 1 gm. $CaCO_3$	13.72			
200 mg. D. B.	9.09	9.30	6.02	36.83
200 gm. D. B.	9.52			

TABLE XI. SOIL E.

Sources of Nitrogen.	Nitrate nitrogen. mg.	Aver. of nitrate nitrogen. mg.	Increase over untreated portion. mg.	Percent nitrified.
Nothing	5.53	5.39		
Nothing	5.26			
200 mg. D. B. + 1 gm. $CaCO_3$	18.02	18.12	12.73	77.83
200 mg. D. B. + 1 gm. $CaCO_3$	18.22			
200 mg. D. B.	13.42	13.32	7.93	47.92
200 mg. D. B.	13.22			

TABLE XII. SOIL F.

Sources of Nitrogen.	Nitrate nitrogen. mg.	Aver. of nitrate nitrogen. mg.	Increase over untreated portion. mg.	Percent nitrified.
Nothing	6.25	6.10		
Nothing	6.06			
200 mg. D. B. + gm. $CaCO_3$	20.02	19.10	13.00	79.56
200 mg. D. B. + gm. $CaCO_3$	18.18			
200 gm. D. B.	14.28	14.71	8.61	52.69
200 gm. D. B.	15.15			

The preceeding tables show a variation in the rate of nitrification in the different soils but those that gave low results in the first set also gave low results in the second and those that gave high results in the first set gave high ones in the second. The main difference in the results is that the nitrate-nitrogen formed in the second set, even in the blanks, is in all cases higher than in corresponding samples of the first set. What the factors may be that caused this, the writer is unable to say positively. Perhaps the dif-

ference of temperature during incubation period is partly or wholly responsible for it; perhaps also it is due to the time interval between sampling and incubation, the soils of the first set having been dried for 8 days and those of the second set for but 2 days before incubation.

Apparently more favorable conditions in this second set of experiments have permitted a more rapid rate of nitrification which is noticed even in the check experiments where no nitrogenous matter was added to the soil. Since the soils all contain from 0.07% to 0.10% of nitrogen in their natural condition, there is accordingly from 70 to 100 milligrams of organic soil nitrogen in the 100 milligrams of soil. The fact that the nitrate-nitrogen formed in the checks amounted to scarcely more than 2 to 6 milligrams under the most favorable circumstances, is conclusive proof that the nitrogen of the local soils is of a form or in a state of combination not readily susceptible to transformation by the nitrifying bacteria. The amounts of ammonium sulphate and dried blood used in the experiments contain but very little nitrogen in comparison with that already present in the soil, and yet this small addition of nitrogenous material was sufficient to accelerate the rate of nitrification enormously. It is therefore to be concluded that the nitrogen of fertilizers such as these is more readily converted into nitrate than is the ordinary soil nitrogen, and for this reason is more available for the growth of plants than the latter. In soils therefore which have apparently a sufficient amount of nitrogen to supply the need of ordinary crops, nitrogen starvation may actually take place because of the fact that the soil nitrogen is often nitrified with difficulty. The application of ammonium sulphate, dried blood or other similar fertilizer is then one means of furnishing the corps with their proper supply of nitrates.

It is found in these experiments that in every case the application of calcium carbonate has an accelerating effect on the nitrification of dried blood, the average percentage gain over experiments in which no calcium carbonate was used being 60.25%. This application of 1 gram of calcium carbonate to 100 grams of soil is equivalent to an application of 15 tons per hektar of land, considering that the weight of the surface soil of one hectar of land in round number is 1500 tons. It appears then that limestone applied to local soils at the rate of 15 tons per hectar accelerated the rate of nitrification by half. Probably a smaller application would have had a similar action.

It is supposed that this action of lime is due to its alkaline reaction. It neutralizes the nitrous and nitric acids formed by the bacteria and so eliminates substances that, if permitted to accumulate, would inhibit bacterial action. The process is analogous and closely related to the principle of mass action in analytical chemistry.

A third set of experiments was next undertaken to study the rate of nitrification in soils having different moisture contents. The effect of addition of sand to increase the porousity of the soil was also studied, as well as the result of using 1 gram of fresh soil for inoculation instead of a water infusion of soil. Finally the effect of magnesium carbonate on nitrification was studied. These experiments were all undertaken with Soil A. The samples were taken from the field January 20, 1915.

These experiments were conducted in general as those described above, but some of the details were different. On account of the lack of a sufficient number of Petri dishes to cover the beakers, filter papers were used with rubber bands to hold them in place. The evaporation during an interval of 10 days was therefore so great that it amounted to the average of 11 grams while the loss by evaporation in the same time in the preceeding experiments was about 3 grams. One result of this is a lower rate of nitrification. For this reason the writer does not believe that this part of his work is perfectly satisfactory. On the other hand, the results to be found in the following tables seem to confirm nitrification experiments undertaken elsewhere.

The first of these experiments was for the purpose of determining the effect of soil moisture on the rate of nitrification, dried blood being used. In four experiments the soil contained 20% water and in the remaining four, 40%. Half of the beakers contained 1 gram each of calcium carbonate. The source of nitrogen used in every case was 200 milligrams of dried blood. The results of the quantitative determinations of nitrate-nitrogen, after 4 weeks incubation at room temperature (24-30° C.) are found in the following table:

TABLE XIII.

Percent Moisture.	*Sources of Nitrogen.*	*Nitrate nitrogen. mg.*	*Aver. of nitrate nitrogen.*
20	200 mg. D. B.	------	2.52
	200 mg. D. B.	2.52	
	200 mg. D. B. + 1 gm. $CaCO_3$	1.16	1.17
	200 mg. D. B. + 1 gm. $CaCO_3$	1.19	
40	200 mg. D. B.	6.97	7.03
	200 mg. D. B.	7.09	
	200 mg. D. B. + 1 gm. $CaCO_3$	12.00	12.12
	200 mg. D. B. + 1 gm. $CaCO_3$	12.25	

It will be noticed that the calcium carbonate exerts a great stimulating effect in the soil containing 40% of moisture, while if the content of moisture in the soil is but 20%, the calcium carbonate appears to be slightly unfavorable. Of course the optimum percentage of moisture in the soil must depend on the nature of the soil since its water holding capacity will vary with the size of the soil particles. In many cases the optimum percentage in a sandy soil has been found to be 15—20%, while 40% was found in the experiments above. Since the soil used here was a heavy clay, it could naturally absorb more water without interferring with aeration.

The next experiments were undertaken with a view of determining the effect of the addition of sand to the soil in increasing aeration. Here 25 gm. of sterile sand free from shells ($CaCO_3$) were added to 75 gm. of soil. Four experiments were run using 200 mgm. of dried blood in every case and making the moisture content up to 22%. Two of these were treated with 1 gram of calcium carbonate. The amounts of nitrate-nitrogen after incubation are to be found in Table XIV.

TABLE XIV.

Sources of nitragen.	*Nitrate nitrogen mg.*	*Average of nitrate nitrogen. mg.*
200 mg. D. B.	4.61	4.54
	4.47	
200 mg. D. B. + 1 gm. $CaCO_3$	6.82	6.74
	6.66	

The increase in this set of experiments over those of the set last described containing 20% moisture was from 80% to over 500%. This difference is not to be accounted for by the mere presence of 2% extra moisture, but must be due to better aeration produced by the addition of sand to the soil. These results are, however, somewhat lower than the corresponding data in Tables I and VII, a result that proves that nitrification experiments are not conclusive if the samples used in a comparison are not taken from the field at the same time and incubated under similar conditions of temperature and moisture.

The next experiments were on the effect of using 1 gram of fresh soil instead of a water infusion for inoculation, the results being given in Table XV.

TABLE XV.

Inoculated with	*Sources of Nitrogen.*	*Nitrate nitrogen mg.*	*Average of nitrate nitrogen. mg.*
1 gram of fresh soil.	200 mg. D. B.	1.82	1.87
		1.93	
10 c. c of water suspension. Rep. Table XIII.	200 mg. D. B.	------	2.52
		2.52	

It appears from the above table that more vigorous nitrification is secured by using a water suspension of bacteria for inoculation than by using fresh soil. But these results are perhaps in doubt because of the fact that the moisture content of the soil could

not be closely controlled on account of rapid loss by evaporation.

The next experiments of the series were to study further the effect of the different degrees of moisture. Six experiments were run, two that contained 10%; two 15%; and two others, 25% of moisture. The results are given in Table XVI.

TABLE XVI.

Moisture	*Sources of Nitrogen.*	*Nitrate nitrogen. mg.*	*Average of nitrogen. mg.*
10%	200 mg. D. B. + 1 gm. $CaCO_3$	0.32 0.31	0.31
15%	200 mg. D. B. + 1 gm. $CaCO_3$	0.32 0.34	0.33
25%	200 mg. D. B. + 1 gm. $CaCO_3$	0.39 0.44	0.41

In these experiments the soil was dried in an oven at 100° C. for more than 2 hours. The purpose of drying was to obtain a soil sample that after inoculation of 10 cubic centimeters of a bacterial suspension would contain only 10% moisture.

Of course in so doing the soil was sterilized, for nitrite bacteria are killed at 55° C. in 5 minutes, nitrite bacteria at 45° C. at the same length of time. (1)

In the experiments the results of which are found in Table XVI but a small fraction of a milligram of nitrate-nitrogen was found in any of the breakers. This appears to show that the sterilization of the soil by drying, in some way prevented the bacteria introduced by inoculation from multiplying sufficiently during the course of the experiments to bring about vigorous nitrification. Perhaps this only shows that the moisture content of the beakers was in every case too small.

The last set of experiments was on the effect of magnesium carbonate on nitrification. At the end of these experiments, nitrites as well as nitrates were determined, since former investigations had shown that the use of magnesium carbonate tends to interrupt the nitrification process at the stage when nitrites are produced. The determination of nitrite was made by a modification of the colorometric method of Griess, in which solutions of sulphanilic acid and alpha-napthylamine acetate were used to develop a pink color that was compared with the color of a standard nitrite solution. The following data give the results of quantitative determinations after incubation for 4 weeks:

TABLE XVII.

	Sources of Nitrogen.	*Nitrite nitrogen. mg.*	*Aver. of nitrite nitrogen. mg*	*Nitrate nitrogen. mg.*	*Aver. of nitrate nitrogen. mg.*
Actual experiments.	200 mg. D. B + 2 mgm. $MgCO_3$	1.62 1.29	1.45	1.43 1.56	1.54
Rep. from Table XIII.	200 mgm. D. B. 200 mgm. D. B.			---- 2.52	2.52

(1) Warrington, Journ. Chemic. Soc., *59*, (1891,) 484.

From the data above, it will be observed that the nitrification in the presence of magnesium carbonate is about 40% lower than with dried blood alone. Since magnesium carbonate has a pronounced toxic effect in nitrification, (1) this lowering of the rate of nitrification is undoubtedly due to the effect of magnesium carbonate.

In these cultures an average of 1.45 milligrams nitrite-nitrogen was found, while in a set of six similar experiments run without the addition of magnesium carbonate there was found but a mere trace of nitrite-nitrogen which was estimated by the very delicate colorometric used as being about 0.0075 milligram. This confirms in a rather striking way the statement made by previous investigators that the use of magnesium carbonate tends to interrupt the nitrification process at the stage of nitrite formation, while in absence of magnesium carbonate the second stage of nitrification is able to proceed so rapidly that the amount of nitrite present at any given moment is very small indeed.

Conclusions.

1. Different soils show different rates of nitrification, even though they be chemically much the same. A part of this difference is doubtless to be attributed to the influence of the present and preceding crops on the bacterial flora of the soil.

2. Some soils originally in cogon grass that had grown crops continuously for three years gave a low rate of nitrification amounting to from 5.55-7.84 milligrams in a 100 gram sample of soil during four weeks incubation at room temperature in the presence of 16.34 milligrams of nitrogen in dried blood.

3. Two plots tested that had been but recently brought under cultivation give a much more rapid rate of nitrification amounting from 8.27-14.71 milligrams under the same conditions.

4. The nitrification with ammonium sulphate is about 50% more rapid than that of dried blood.

5. It is possible that the time interval between sampling and incubation influences nitrification.

6. Lime applied 15 tons per hectare increases the rate of nitrification by more than half.

7. Rapid evaporation during the time of incubation lowers the rate of nitrification a great deal.

8. The addition of 25% sand to clay soil increases the rate of nitrification as much as 80%.

9. By sterilizing the soil by heat, nitrification is almost entirely suppressed, even though the soil be afterward reinoculated.

10. Magnesium carbonate interferes with nitrate formation to as much as 40% and causes nitrites to accumulate in the soil.

Recommendations.

1. Since calcium carbonate has a decided effect in increasing the rate of nitrification in local soils, it is recommended that limestone be added to the soil at a rate which actual tests show to be profitable. The percentage of nitrogen of the College Farm soil is very low, seldom exceeding 0.1%, and this small store of nitrogen is converted to nitrates so slowly without the addition of calcium carbonate that most crops are always in danger of nitrogen starvation. The addition of limestone has not only been shown to accelerate the nitrification of dried blood used as a fertilizer, but it even increases very decidedly the rate of nitrification of the store of nitrogen in the soil.

2. Since it is found that magnesium carbonate hinders nitrification, the calcium carbonate to be applied must contain as little magnesium carbonate as possible. Otherwise there is danger of the formation of nitrites in toxic quantities.

3. Dried blood is to be preferred to ammonium salts as a fertilizer because it is readily nitrified besides being less subject to loss by leaching than are ammonium salts.

4. The soil should be kept in optimum moisture condition; that is, it should contain from 20—40% moisture.

5. Surface cultivation should be frequent in order to check rapid evaporation which lowers the rate of nitrification.

6. It has been shown that soil that has been sterilized by heat but very slowly regains its nitrifying power even though it be freshly inoculated. For this reason, the practice of cleaning cogon lands by burning is to be discouraged, if the land so cleared is to be made to produce crops immediately, without the addition of nitrates.

Acknowledgement.

The writer wishes to express his thanks to Professor H. G. Deming for the help given in the preparation of this paper.

(1) W.P. Kelley, "The Effect of Calcium and Magnesium Carbonates on some Biological Transformations of Nitrogen in Soils", (Bul. Univ of Calif. Vol I, 3, (1912,) 49.)

SUGAR MANUFACTURE AT THE CALAMBA SUGAR ESTATE

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Introduction.

The main object of this paper is to give a detailed description of the course of cane sugar manufacture in a well equipped modern *central*. Modern mills are the greatest need of the sugar industry in the Islands, and offer an exceptionally fine field for investment both for capitalists and for the growers who supply the central mills with cane. The success of a central mill depends on many things, but mainly, on a large and continuous supply of cane. Sugar mills are like other industrial concerns in this respect: they are equipped with costly and intricate machinery, which must be worked as nearly full time as possible to earn a profit on the investment. The greater the quantity of cane put through, the smaller the relative cost of treatment. The efficiency of the machinery will affect the extraction: the greater the amount of sucrose extracted, the better the return. This means that the machinery must be kept up at the highest state of efficiency to secure the best results.

The Islands now have twelve centrals, but nine of these have a capacity of not more than 200 tons of cane in 24 hours. The largest of the Philippine centrals is the one which the writer is describing, the next in size is the Mindoro central, and third comes that at San Carlos (Occidental Negros), which has a capacity of 800 to 1000 tons of cane in 24 hours. Five of the small ones are located in Negros Occidental and are owned by the local cane growers; one is in Iloilo; and the other three are in Luzon, at Muntinlupa, Calamba, and Nasugbu.

The Estate.

The Calamba Sugar Estate is about 6 to 7 kilometers west of the town of Calamba, and its total area is 10,000 hectares. The estate had not been cultivated long when bought by the company in 1910, and had been growing cogon *(Imperata exaltata)*, and small trees, principally madre cacao *(Gliricidia sepium)*. Only about one half of the total area is available for cane. The area planted this year is about 1000 hectares, but the coming year 2000 hectares will be under cultivation. Only half of the latter area is expected to be put to ratoon. The canes at hand are mostly Luzon white, though about one tenth of the cultivated area is occupied by Negros purple. Several varieties are being experimented with to determine their ability to withstand the dry season, but so far no results have been obtained as to the quality of the juice they furnish, because they have been cultivated only for seed. Some of the varieties that seem to stand drought are Lahaina, Hawaii 309, Demarara 1135, Hawaii 227, and Louisiana Striped. Much damage to the canes is caused by the locust, which came last year in enormous swarms from Cavite province. They stayed from May till October, and the cane destroyed has been estimated to be about 65 per cent of the crop. Each field, after cutting, is burned over to lessen danger of future insect attack.

The cane of the estate was this year not enough to supply the mill, hence the company made contracts with numerous outside planters of Pampanga, Laguna, and Batangas provinces. Laguna and Batangas provinces grow Luzon white cane; Pampanga, about one-half red cane.

The company uses no work animals in cultivating the land, this being done entirely by machinery. There are three sets of Fowler steam plows, two caterpillar traction engines, and three oil-pull tractors. The last named are used in connection with disc plows of from 3 to 6 discs each.

The cane is transported by a railroad system 18 miles long, with an additional 10 miles of portable track to deliver the cane from the field to the main line. The canes from the provinces named are brought to the factory by the Manila Railroad. There are three Baldwin locomotives used on the main line to pull the cars loaded with cane, while traction engines are used only in connection with the portable track.

The Factory and Mills.

The factory frame is of steel, the roof and walls, of galvanized iron. It is four stories or stages high. The engines and mills are on the first stage; the evaporators, juice heaters, juice scales, filter presses, laboratory, and centrifugals on the second stage; the settling tanks, clarified juice tanks, sulphur box, and crystallizers on the third;

the vacuum-pans, seed tank, and syrup tanks are on the fourth stage.

The mill was designed by the Honolulu Iron Works. Its construction was under the supervision of Mr. Norman G. Campion and required 9 months.

The cars, loaded with cane, as they come to the factory, are weighed one at a time before and after they are emptied in order to find the weight of cane crushed. They are discharged by a large mechanical rake having a universal motion, which enables the operator to move it at any height from the body of the car to the top of the load over the entire length of the car at any desired rate, thus keeping the carrier evenly loaded. The cane carrier consists of a galvanized steel endless belt parallel to the railway track or cane platform. On approaching the mill house the cane carrier gradually ascends and passes into the building at an elevation sufficient to deliver the cane into the crusher. The crushing portion consists of four sets of 3-roller mills and a crusher, the latter being of the helical groove or Krajewski type. It is in a very strong frame fitted with pressure springs, so loaded that the rollers mesh with each other like gear wheels. The length of the crusher is 78 inches and its diameter is 32 inches.

The rollers of the mills are of the usual grooved type. Their length and diameters are all the same:—78 inches by 34 inches. The grooves are 4-pitch, i. e., there are four grooves per inch and the height of each groove is one fourth of an inch. There are "hydraulic pressure regulators" at each end of the top roller, each working independently, a device which secures a high extraction of juice from the cane. This innovation is of importance, because the pressure on the bagasse can always be equalized, thus securing uniform extraction of juice throughout. In old style mills the pressure comes from one source and the pressure-pipe extends above the mill, where it branches to each end of the top roller. Very few factories in Hawaii have the new device.

The capacity of this set of mills ranges from 45 to 50 metric tons of cane per hour and the extraction of sucrose in the cane is from 94% to 96%. The total pressure on the rollers varies from 300 to 400 tons. The crusher and the first and second mills are driven by a low-speed, high duty engine of the Corliss type, while the third and fourth mills and the bagasse carrier are driven by an engine similar to the first, but larger. The first engine is of 300 horsepower, and makes 37 to 40 revolutions per minute; while the second is of 350 horsepower, and makes 40 to 44 revolutions per minute.

The cane goes down to the first mill by gravity and the bagasse emerging from it is immediately sprayed over by the diluted juice from the third mill. The bagasse from the second mill is sprayed with the more dilut juice from the last mill; and as it emerges from the third mill, by hot condenser-water from the quadruple effect. The amount of water commonly added is ten per cent of the weight of the cane. There has been much difference of opinion as to the relative advantages of hot and cold maceration. The bagasse, as it emerges from the mill, expands immediately. The water is sprayed in with a considerable force the instant the bagasse leaves the rolls. Hot water is likely to dissolve more gummy matter from the bagasse, and tends to swell the latter, but probably is still preferable to cold water, since Geerlig states that there is no appreciable difference in the purity of juices obtained by hot and by cold maceration (1). The juice extracted from the crusher and the first mill will hereafter be called the first mill juice, to distinguish it from the mixed juice which contains maceration water.

The mills have short bagasse carriers between them, and from the last mill there is a bagasse conveyor passing above the furnaces and provided with a device by which the amount of bagasse delivered into each stoker may be regulated. The amount of moisture in the bagasse runs from 45 to 48 per cent, the fiber, from 48 to 50 per cent, and the sucrose about 3.5 per cent. Early in the season (December) the fiber in the cane was 8.5 per cent. This of course varies with the age of the cane and the locality; the cane ground in March showing 11 per cent fiber. It appears also that upland canes are fibrous and light, while lowland canes are less fibrous and heavy.

The are 8 boilers, set single, of the return tube type. Each furnishes 250 H. P. making in all 2000 H. P. available, the fuel being supplied entirely by bagasse. This kind of boiler gives a considerable economy in fuel

(1). Geerlig's, "Cane Sugar and Its Manufacture." (1909) p. 103.

and a high percentage of combustion, and there is always plenty of bagasse stored up every time the mill stops. The boiler water is regularly tested for sugar, acidity, etc. Waste molasses is sprayed on the bagasse to furnish extra fuel.

Clarification.

The juice from the mill is pumped up into two cylindrical Howe scale-tanks filling one at a time. These tanks work independently of each other. When one tank is full, the scale is balanced while the other is filling, then a ticket is punched through a hole at the lever arm, when the weight of the juice is recorded on it. To this tank is added, milk of lime usually about 2 to 3 kilos of lime per tank of 5500 kilos juice. The volume of each weighing tank is about 6.84 cubic meter sand the weight of the juice usually recorded here is about 5500 kilos per tank.

The mixed juice storage tank is rectangular in form holding about 156 hectoliters. The bottom of this tank contains 8 four-inch hot water pipes carrying water from the condensed water storage tank on the pan floor to the mill for maceration purposes. The juice in the storage tank is therefore partially heated, which means economy in steam. A 5-inch discharged pipe at the bottom of the tank leads to the mixed juice pump and then to two Deming superheaters, commonly called juice heaters.

These heaters are placed horizontally about one foot apart. They are of the same type and size, each having a diameter of 84 inches and a length of 146 inches. Their ends are tightly closed, and the cylindrical space is fitted with 176 copper tubes, each running lengthwise with a length of 142 inches and an inside diameter of 1.4 inches for each tube. Live or exhaust steam is admitted to the inside of this drum. Number one heater is usually heated by exhaust steam to a temperature of 140 degrees to 160 degrees Fahrenheit, and number two heater with live steam to a temperature of 212 degrees to 220 degrees Fahrenheit. The juice pumped from the storage tank goes from one end of a juice heater through six tubes, thence back through an overlying set of six tubes, the process being repeated many times until the juice finally passes out through a six-inch pipe leading to the settling tanks. The heating surface of each heater is about 763 square feet. This apparatus has many advantanges, there being decided economy in steam, labor, and space; superheated juice moreover subsides better than boiled juice.

Settling is carried out in closed rectangular tanks covered with asbestos. Each tank is about 4-1/2 feet by 7 feet by 5-1/2 feet. There are in all 14 tanks. Each has a crosswise partition in the middle provided with two holes about six inches in diameter, and an aperture in front at the bottom of this partition so as to have the juice in both compartments at the same level. Each tank is provided with three valves to draw out the clarified juice; one of these is about 2 feet below the top and the other two about one foot above the bottom of the tank. The upper valve and one of the lower ones are at the right of the partition while the other is at the bottom of the tank and at the left of the partition as an outlet to discharge the sediment or mud, which flows into a receiving tank near the filter press. It usually requires about eight minutes to fill a tank, and the clarified juice is drawn out after 20 to 30 minutes after the tank is filled. The clarified juice flows through an open trough and goes to the clarified juice tank ready for the evaporators.

There are seven standard filter presses, manufactured by F. Shiver of Philadelphia, each containing forty-four cakes. The size of each cake is 31-3/8″ X 31-3/8″ X 1-3/8″, and the filtering surface of each filter press is about 600 square feet. The press consists of a series of iron plates and frames placed alternately on the frame of the machine. The plates are corrugated and grooved on each surface, the grooves of each plate connecting with an opening leading to the outside of the plate. A small brass faucet, is fitted to each plate for discharging the juice. Each frame consists of an iron rim open in the center, and carrying one channel through which the juice is pumped, and another through which steam or hot water is forced. The press has a fixed plate at one end with a strong screw for holding the plate and frames. To prepare the press for service a filter cloth made of jute and another made of a mixture of cotton and jute are folded together and placed over each frame. The frames and plates are then shoved together and the head plate is firmly pressed against them by means of the screw. The turbid juice with mud and scum from the settling tanks enters by gravity for about an hour on

opening the valve at the left of the press. When the flow of the juice slackens, this valve is shut and another is opened. The remainder of the turbid juice is pumped in by the air displacement pump working at 45 pounds pressure. The juice passes through the filter cloth, trickles down the grooves in the plates and runs into a small gutter at the bottom, and out through the faucet into the juice trough along the side of the filter press. After the pump has run for about 2-1/2 hours the flow slackens, indicating that the frames are filled with mud. This mud, known as the filter-press cake, usually contains about 7.5 to 8.5 per cent of sucrose. The pump is stopped, the valve is shut and the water cock is opened for 45 minutes to wash out the remaining sucrose. The steam cock is then opened for 2 hours, to dry out the cake and wash out any sucrose remaining. The sucrose content of the cake is high, due to the fact that the water pipe is not connected with the juice pipe, and thorough washing is impossible. If the wash-water were introduced into the press through the same orifices as the juice, the sucrose left in the cake should not exceed 2 per cent. The recovery of this sucrose in the sediment is of considerable importance on account of the great weight of the press-cake turned out every day, which amounts to 1.5 per cent of the weight of the cane. The weight of the press-cake in one plate is about 20 to 22 kilos, hence (taking the average weight) there will be 924 kilos of cake or mud in one press; and in 7 presses there will be 6,468 kilos of cake altogether. If the average percentage of sucrose in the filter press cake is 7.5%, the total sucrose lost in the cake will be 486.5 kilos each time the presses are filled. This loss is shown in comparison with others in a table given later. The press is opened, the cakes damped out for removal, and the filter press cloths sent to the laundry. The filter press is again ready for work as soon as cleaned and refitted with clean filter cloths. The cakes are thoroughly ground up in a trough below the press floor, and fall into a car, which takes them to the field for fertilizers. The clarified juice from the filter press is pumped to the mixed-juice storage tank below the juice scale, and but seldom to the clarified juice tank, since the juice from the filter presses is heavily limed, and if it were to be added to the clarified juice some precipitation would occur.

Evaporation.

The set of evaporators in use is a standard quadruple effect, each evaporator but the last having double vapor pipes leading from its dome to the steam belt or calandria of the next evaporator. The evaporators each have 16,000 square feet heating surface. The steam belt (calandria) of each evaporator consists of tube plates and copper tubes placed inside of the body of the evaporator, and resembles in construction a very short steam boiler with the multiple tubes arranged vertically. The diameter of each calandria is 10-1/2 feet and the length of each tube is 4-1/2 feet. Each calandria has 1,494 tubes having a diameter of 1-3/4 inches; and is also provided with a live steam connection. The diameter of the vapor pipes in the first effect is 18 inches, in the second and third is 22 inches, and in the fourth is 48 inches. The relatively great size of the last pipe gives a low velocity to the vapor. The ring-shaped juice inlet has a diameter of 5 inches, and the feed pipe connected to it lies below the calandria. It is perforated to allow an even feed, the juice in this case being more uniformly heated. This construction is more efficient than that employing a single pipe without perforations. The pipes for the incondensible vapors are 2-1/2 and 3 inches in diameter. They all lead to the fourth evaporator. The pipe for injecting water has a diameter of 4 inches. The juice occupies the space above and below the steam belt and inside of the vertical tubes; accordingly when steam or hot vapor is admitted to the inside of the belt it heats the shell and tube and raises the temperature of the juice. The vapor from the first evaporator heats the juice in the second and that from the second heats the third, etc. The vapor from the last evaporator is condensed in a special condenser where it comes in contact with a stream of cold water. This condensed water flows to the cooling tower after which it is pumped up to the tank outside the factory for condensing the vapor from the vacuum-pans and from the fourth evaporator. The condensed water inside the calandria of the first evaporator goes back directly to the boiler while the condensed water from the second, third, and fourth calandrias is pumped to the storage tank at the pan floor for maceration, for washing the press-cake, for washing the sugar in the centrifugals, for boiling out the vacuum-pans, etc. The

greater portion of the condensate runs to the hot-well to be used as boiler feed-water.

The clarified juice goes to the first evaporator by gravity and by vacuum of 2 inches. Exhaust steam is generally used to boil the juice. The vacuum in the second evaporator is 5 inches, that in the third is 15 inches, and that in the fourth is from 24 inches to 26 inches. The juice passes in succession from the first evaporator through to the last one of the series and is gradually concentrated to syrup of 70 to 76° brix (1.351 to 1.389 specific gravity), after which it is pumped into the syrup storage tanks on the pan floor. Each of these tanks holds about 3244 gallons of syrup and, as the average number of tanks filled in twelve hours work is 6.5, this makes about 21,086 gallons per day of 12 hours.

From the syrup tanks the syrup is drawn into the vacuum-pans for final concentration. There are three dry-system vacuum pans of the same size and form, each holding about 18 tons of massecuite. Their construction is similar to that of a single body of the quadruple effect. The pans are of "Express system calandria" and are manufactured by the Honolulu Iron Works, as are the evaporators. The calandrias or steam belts of the pans have larger tubes than they have quadruple effects. Both surfaces of the calandria slope to the center of the pan, where there is a large down-take immediately above the gate in the bottom through which the massecuite is discharged. The tubes pass from the upper to the lower surfaces at an angle with the walls of the pan. When heated the liquid in these tubes passes downward toward the center of the body, thence to the outside, where it rises to the top of the liquid. This system is said to give a much better circulation and more economical evaporation of the syrup than the standard copper-coil heating arrangement ordinarily used in vacuum-pans. Each pan is provided with two valves for exhaust steam and two for live steam, with vacuum-gauge, steam-gauges, pipe drainage, and proof-sticks. The vapor from each pan is condensed when it meets the stream of cold water at the end of the vapor pipe. The condensed water and the remaining uncondensed vapor pass together to a special condenser where more water is injected. This mixture then flows down to the cooling-tower. The condensed water from the calandrias of the vacuum-pans goes to a Blake pump connected with two pipes from each pan. This hot condensate is fed directly to the boilers, thus saving heat and fuel, for the pan is always heated with live steam. The diameter of the central downtake is 23 inches and the diameter of the pan is 8 feet 9 inches. The heating surface of each pan is 606 square feet, the diameter of each copper tube is 3 inches. that of the sliding gate, of the pipe to discharge the massecuite to the crystallizer, 12 and of the vapor pipe, 42 inches.

The water used to condense the vapors from the pans and evaporators is taken from the artesian wells and cooler. This water is pumped by a Duplex plunger pump of 700 H. P.

The vacuum in the evaporators and in the vacuum-pans are produced by a central vacuum pump-system. The main disadvantage of the one vacuum-pump system is that the vacuum fluctuates both in the evaporators and in the pans when either is in trouble, and when the pump stops due to breakage, both evaporators and pans have to stop also. The advantage of a central pump-system is the saving in steam, labor, cost and space. If there are separate pumps there will be more steam pipes, a higher first cost, and greater space requirement. Economy in steam is the principal reason of having one pump. Pan No. 3 is used only for boiling B (second grade) sugar and pans Nos. 1 and 2 are used for A (first grade) sugar. The making of sugar in the vacuum-pans varies according to the type of pans and the knowledge or skillfulness of the sugar boilers. The method of operation is as follows: The vacuum-pan is connected to the vacuum pump, and all openings into the pan are closed. The syrup is drawn in when the manometer shows a vacuum of 25 to 26 inches. The quantity drawn should be enough to fill the pan to a point one and one-half feet above the calandria, so that by the time it has been concentrated to a point when small crystals are beginning to form, the surface of the syrup will be just above the upper proof-stick. The exact point of granulation can be detected either by the consistency of the the liquor, or by examination of the size and number of crystals on a glass slide. The next operation after the point of granulation has been reached, is to draw in more syrup little by little for the growth of the crystals, allowing fresh syrup to enter as the water evaporates. The chief danger that the sugar boiler must avoid, is the formation of a new set of fine crystals (false grain), which would impede

the purging of sugar in the centrifugals. Crystals should be formed in sufficient number and of regular and moderate size. When the pan is about two-thirds full, it is allowed to concentrate. Very often molasses is drawn in more than 56 per cent purity, and if the grain is uniform. The amount of molasses used varies: often it is about one-fifth to one-sixth of the total syrup taken. When the pan is full the vacuum is raised to 27 inches and no more syrup added, the contents being allowed to evaporate to consistency correct for the strike of the pan. There are many methods for judging this point, but generally it is determined by inspection samples formed into a cone between the thumb and fore finger. The practical man can judge this point easily by looking at the movement of the massecuite through the glass.

When evaporation has been carried to the proper joint, the steam and water are turned off, the vacuum-valves are closed, and the the air-brake is opened. The massecuite falls into an open mixer provided with stirrers and located just above the centrifugals. If it is desired to put the massecuite into the crystalizer the gate is shut off and the valve near it is opened. The massecuite then flows to the trough and falls into the crystallizer. At times a portion of the massecuite is left in the pan to serve as a nucleus for a new charge; this is done especially when the grain is small. After every strike, when the pan is empty, steam is injected to blow it out, so as to avoid charring by over-heating of the massecuite sticking to its interior, an occurance that would produce dark colored lumps in the sugar of the next strike.

"First molasses" of a purity lower than 56 per cent is also boiled to a certain consistency, then the steam and water are turned off and the vacuum is lowered to 15 inches. After a few minutes small grains appear; and if they are large and numerous enough the pan is again started. Then molasses is drawn in little by little as the liquor becomes more concentrated, and when the pan is full the contents is boiled down. The point of strikes can be detected by the stiffness of the massecuite when taken between the thumb and the forefinger or put into the water. The operation of striking is the same as with "first sugar" except that the second grade massecuite always goes into a closed crystallizer to permit the crystals of sugar to grow in size. The massecuite in the crystallizer is constantly stirred up, and centrifuged after a week. The sugar obtained is called B sugar. This is not put in bags but is mixed with syrup and pumped up to a tank. The mixture now is called the "seed grains" and is afterward boiled in the pan as if it were a cut from a strike. In this case the charge of the pan is drawn in on a part of a previous strike, and molasses added before the final concentration. The massecuite is centrifuged without delay and the sugar produced is A sugar.

The molasses from B sugar is pumped outside into big tanks and is for sale, but some is burnt with the bagasse in the furnace. It should be noted that the average apparent purity is about 30% a very low figure in comparison with the purity of final molasses in other factories in the Islands (1). The lower the purity of the final molasses the more is the saving especially in a factory like this, which turns out each day several tons of waste molasses.

There are 14 closed and unjacketed crystallizers underneath the pan floor, each equipped with a stirring device for keeping the massecuite in motion for a period of a few hours or even for several days, in case of low grade sugar or massecuite. This stirring aids in the building up of the sugar crystals by any crystallizable sugar which may remain in the massecuite, and keeps the material in a semi-fluid state so that it will flow into the centrifugals for purging. The stirrers of the crystalizers are driven by two motors which drive the shafting connected to stirring devices. Each crystallizer holds about 16 tons massecuite and has a capacity of 770 cubic feet.

The sugar centrifugals are an essential part of a modern factory. The machines are made in batteries of seven arranged in continuous iron frames with the necessary supports and connections for the operation. There are two batteries or 14 machines, but seven of these are used only for B-sugar and the other seven for A-sugar. The shafts of these batteries are driven by an engine of 200 H. P. Each centrifuge is of the solid-spindle type; the diameter of the basket is 40 inches and each makes 1000 to 1200 revolutions per minute. A large opening is found in the bottom of the basket, which is closed during the operation by a conical brass and iron cover fitted around the shaft. Each basket has two sieves around the

(1) "Philippine Agricultural Review" Vol. VII, No. 7, p. 300.

inner side; the outer having a larger mesh than the inner one. The latter is not fastened, but is merely placed around against the outer sieve. There is a receiving trough in the casing of the machine just under the basket into which the molasses thrown out of the sugar is caught. Centrifuging consists in placing 150 to 200 kilos of massecuite in the basket, after which it is set in motion and the centrifugal force thereby generated throws out most of the molasses through the fine perforations in the wall of the basket. It is further purged by throwing a fine spray of about 500 cc. of water on the sugar contained in the basket, while the latter is in motion. Steam is also always used. The washing depends largely upon the grade of sugar which it is desired to make at a given time. The automatic plow used for removal of the sugar from the sieve was found to injure the latter, and its use has been abandoned. The sugar falls through the opening in the bottom of the basket to a trough provided with stirrers or mixers to break the lumps, and passes thence to the sugar baskets carried by an endless chain to the drier. The drier is a disk of galvanized iron rotating at high speed, on which the sugar from the baskets falls, to be thrown with some force against the peripheral wall. After emerging from this apparatus the sugar is packed in uniform jute bags, each holding 52.6 kilos. Automatic scales for weighing sugar have not been installed. The bags are sewed by a sewing machine, then placed on an endless conveyor which takes them to an adjoining warehouse ready for shipment. The A-sugar dried in 12 hours work ranges from 1500 to 1600 bags.

Chemical Control.

This factory has a good chemical laboratory of the mill equipped with all the apparatus and supplies required in the analysis of cane, juice, bagasse, fiber, syrup, molasses, massecuite, and sugar. The sugar chemist here is an American who is at the same time factory superintendent. He has three Filipino assistants for calculations, analysis, and sampling.

DON'T STOP!

By Rudyard Kipling

If you stop to find out what your wages will be
And how they will clothe and feet you,
Willie, my son, don't you go on the Sea,
For the Sea will never need you.

If you ask for the reason of every command
And argue with people about you,
Willie, my son, don't you go on the Land,
For the Land will do better without you.

If you stop to consider the work you have done
And to boast what your labor is worth, dear,
Angels may come for you, Willie, my son,
But you'll never be wanted on Earth, dear!

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EDITORIAL.

The Revista Economica, in the editorial of its June issue, after dwelling on the importance of agriculture to these Islands, pointed out with great emphasis that it is the duty of the government to do its best to improve agriculture and the lot of the agricultural classes. The periodical mentioned cites some of the farmers' troubles, and asks what facts are established as a result of scientific investigations carried out in the Philippines regarding the varieties of sugar cane most suited to this country, or the effect of fertilization of coconuts upon the production of copra and coconut oil. It asks what experimentation has been done on the culture of abaca, coffee, tobacco, and cacao. Finally, it sums up the series of questions by asking if there is in these Islands a real *Central Agricultural Experiment Station.*

It is our understanding that the Philippines have never possessed a central agricultural experiment station, and we believe its early and immediate establishment is essential to the development of Philippine agriculture and to any well-founded agricultural education. To understand the need of such a central agricultural experiment station, we must bear in mind that the factors that control the life of plants and animals vary greatly in different parts of the world. Species of plants or animals well adapted to temperate conditions can not be expected to do well in the tropics. If, for example, a variety of corn is successful in the United States, it does not necessarily follow that it will be successful in the Philippines. It has to be tried and tested before it can be recommended for local cultivation, no matter how great its success abroad. In acclimatization work at this College, we have found that the first generation of very superior Iowa corn, was no better than native strains.

What is true of fertilization of different crops in other countries is not necessarily true in the Philippines. Different countries have vastly different conditions of soil and climate, vital factors in the growth of plants. Hence our country, at the beginning of its agricultural development, must not accept without trial the finding of others. Each land must ascertain for itself the effect of existing conditions upon widely different strains and breeds. This truth has given rise to agricultural experiment stations in every progressive country and colony in the world.

Thus the establishment of agricultural experiment stations is no longer in an experimental stage. Japan, in a territory about the size of the Philippines, has established a large central station and about forty branch stations. A country so deeply in debt as is Japan would not be doing this did it not promise to be profitable. The Japanese realize that the present agricultural assets of Europe, Java, Ceylon and the United States are largely due to the work of such institutions.

In these Islands, which are largely agricultural, there is need of a serious consideration of every possible means by which

agricultural may be made more profitable. We need well-organized, comprehensive, and thorough agricultural experimentation for the intelligent improvement of our domestic animals and cultivated plants and for the solution of the numerous problems that now confront us. The work of real experimentation cannot rest upon the farmers' shoulders: it is a proper function of the central government. The government, through efficient agricultural experiment stations, should study our agricultural problems and give to all the people the fruits of its investigations.

Because of the non-existence of a well-developed science Philippine agriculture, the College of Agriculture of the University of the Philippines has had to undertake experimental work in many crops, and has required each student to present a thesis on some practical problem before being graduated. In reality, then, the College of Agriculture has maintained and experiment station, the results of the work of which are already of great importance, and ought to be published and given broadcast to the people.

In this connection, we would direct attention to the fact that the College of Agriculture—though it conducts a small experiment station *for the purpose of securing information necessary for the proper instruction of its students*—has no direct connection with any of the several agricultural experiment stations of the Bureau of Agriculture. A direct result of this has been that a part of the experimentation has been needlessly duplicated; and work of instructional value that might have been undertaken to advantage at the College of Agriculture has not been attempted there, because of the existence of similar investigations in the Bureau. The students of the College have thus been deprived of instruction that the presence at the College of various kinds of agricultural work would have made possible; and the government has not taken advantage of the possibilities for economy that result from the presence on this campus of hundreds of willing pairs of hands.

The obvious remedy for this condition of affairs is to have somewhere in the Islands a real *Central Agricultural Experiment Station*, where the work of agricultural investigations throughout the Islands may be planned and directed. The various branch experiment stations would be but supplementary establishments for the purpose of ascertaining what variations in agricultural procedure are made necessary by the varying climatic and other conditions in different parts of the Islands. The branch experiment stations would also have local demonstration work as an important part of their duties.

Having recognized the need for a real central agricultural experiment station, from which the work of other experiment stations may be directed and with which they will cooperate, the question arises as to its best location. We believed that the College of Agriculture is the natural place for such a central station, since it is possessed of well-equipped laboratories, diversified soils, numerous strains of native and imported plants, and a staff of well trained scientists, members of its faculty. *To recognize the College of Agriculture as a Central Agricultural Experiment Station and to permit it to develope close relationships with the various branch stations of the Islands, would involve very little expense, and would do much to solve the present difficulties.* We believe that, from the standpoint of economy, the selection of this campus as the site of the central station would be the only correct choice. A central agricultural experiment station, being a necessity, and there being a better beginning of one at the College of Agriculture than elsewhere in the Philippines, immediate steps should be taken to develope here an organization fit to take its place beside the modern experiment stations of other progressive countries.